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PROGRESS REPORT ON
THE LOKI WIND CORRECTION COMPUTER

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**PROGRESS REPORT ON
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John F. Moss, Jr.

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November 1, 1953

**Quarterly Report for
July 1, 1953 through September 30, 1953**

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Abstract

This report deals with the functional configuration of a wind correction computer for LOKI and presents tentative circuit designs for several of the servo and computer amplifier units.

The expected physical form of the experimental computer is described within this report.

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Principles of Operation

The principle of operation and the functional configuration of the computer have been presented in an earlier report, (Ref. 1). The present report presents a discussion of the overall block diagram in slightly greater detail and describes the several electronic and electro-mechanical components which have been developed or assembled for use in the computer.

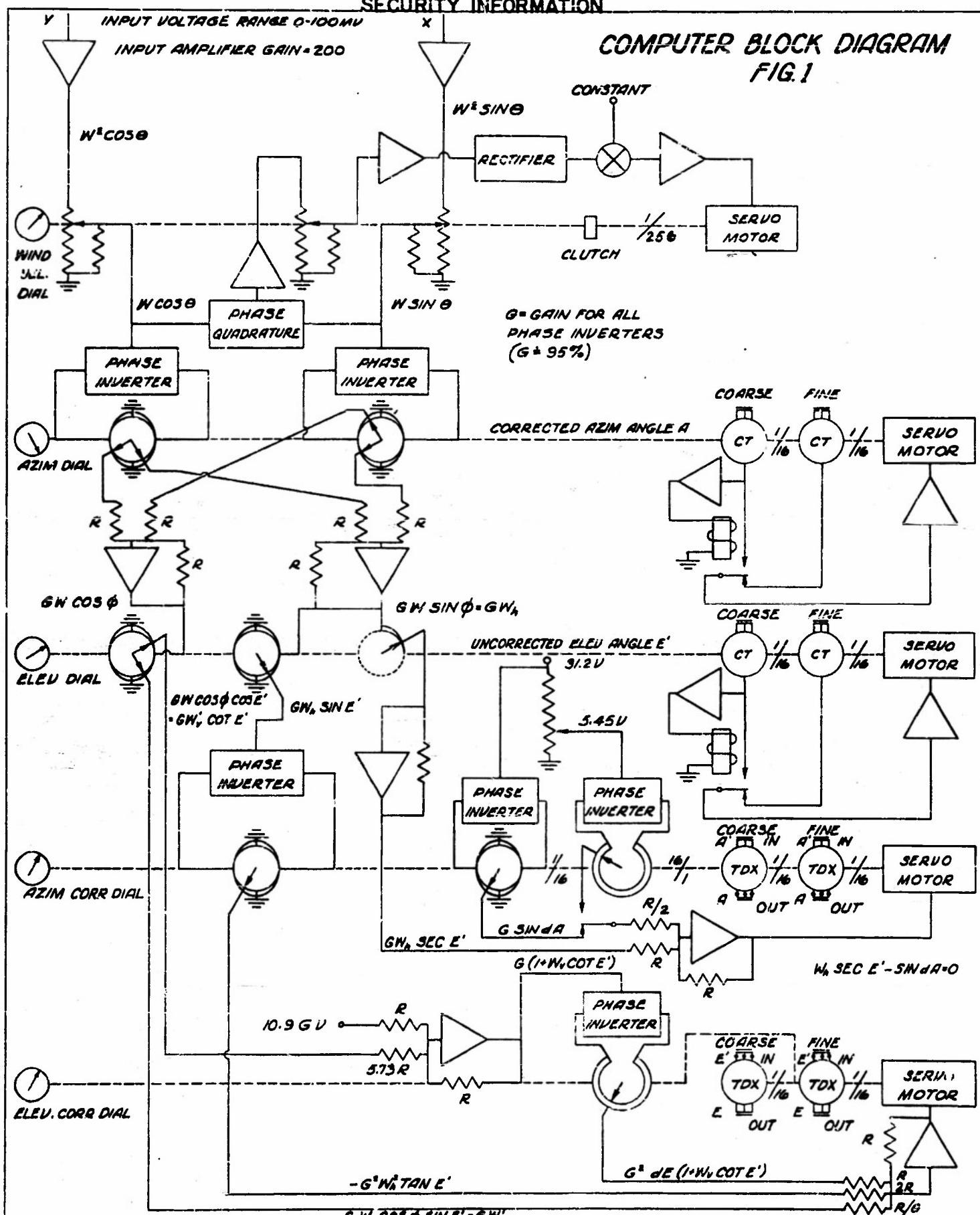
Fig. 1 is a block diagram of the wind correction computer. The five horizontal dashed lines are mechanical shafts positioned by servo motors on the right. The slanted lines crossing the dashed lines represent a change in the turn ratio in an amount indicated in the figure. The potentiometers with the tapered windings represent sine and cosine functions and the non-tapered potentiometers are linear. In the extreme left are indicating dials, coupled with potentiometer transmitters for use during the tests of the prototype computer.

The overall design of the computer utilizes plug-in units. In most instances each type of plug-in unit is used in several locations within the computer. The two input amplifiers, as well as the two amplifiers within the square rooting system, have almost identical characteristics. They are feedback amplifiers and therefore have a gain independent of tube characteristics. The phase inverter plug-in unit is used in 6 positions in the computer. Five summing amplifiers are used, 4 of which add 2 voltages and one of which adds 3 voltages. A single plug-in unit has been devised for use in these 5 positions.

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COMPUTER BLOCK DIAGRAM
FIG. 1



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The servo amplifiers are of three types; one for the square rooting system, one for the azimuth and elevation angles, and one for the elevation and azimuth correction angles. These will be discussed in detail in the following sections. The various functional potentiometers produce the relations required by the equations derived in the First Annual Summary. The inputs x and y in the block diagram are derived from a two-component anemometer whose output is proportional to W^2 , the square of the wind velocity, and ranges from 0-100 mv, which corresponds to a wind velocity range of 0-40 mph. For computational purposes it is necessary to divide this output by the velocity. The method for achieving this is referred to as the square rooting process and is shown in the Block Diagram, Fig. 1. The input $KW^2 \sin \Theta$ and $KW^2 \cos \Theta$ are multiplied by the potentiometers by a factor of R ($R < 1$). The outputs are then added in phase quadrature giving RKW^2 , which is again multiplied by the factor R , due to the similarity of the potentiometers. The output R^2KW^2 is then forced to be a constant by the servo loop. This process requires that the attenuation factor R be proportional to $\frac{1}{W}$, which reduces the inputs to the following stages to $KW \sin \Theta$ and $KW \cos \Theta$. The potentiometers are so loaded that the rotation of the shaft is almost proportional to the wind velocity; this insures a servo loop gain which is nearly constant.

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Due to the range of the square rooting process the launcher will be under-corrected by an amount not exceeding .8 mil for winds less than 4 mph. Since the experimental rocket dispersion amounts to about 8 mils linear standard deviation, this error of .8 mils is consistent with requirements for this computer. In Fig. 2 the input is plotted against the output of the first potentiometer. The gain of the input amplifier is neglected here. It may be seen that below an input of 1 mv. the output is linear with the input and the wind velocity dial is operative. A wider range of square rooting could be achieved, but the accuracy of the process would not be greatly enhanced.

Physical Layout

The experimental model of the wind correction computer will be mounted upon a standard 19" relay rack about five feet in height.

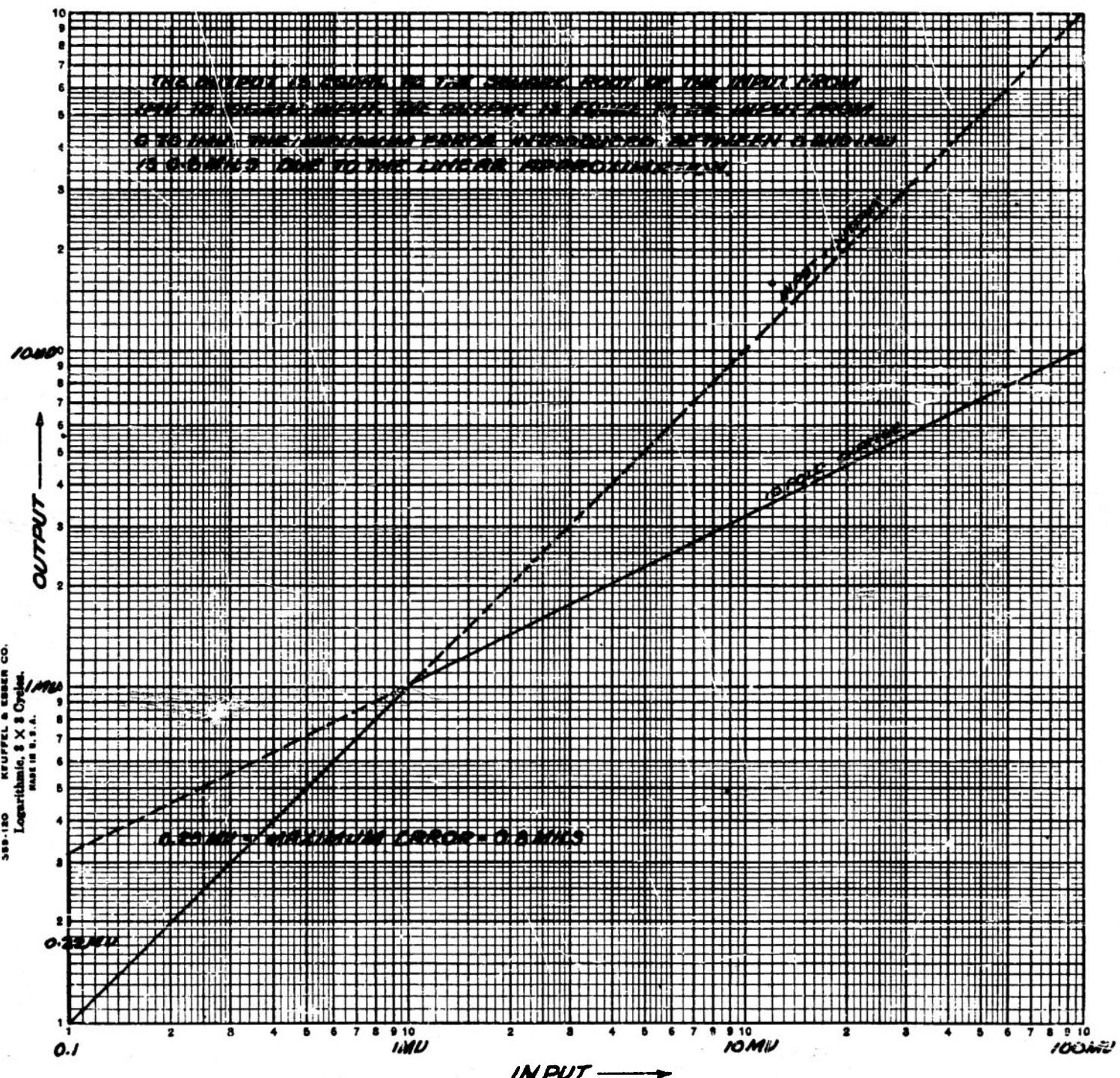
Two conventional regulated power supplies, each capable of delivering 300 volts at 150 ma, have been purchased with rack-mount construction.

The electronic plug-in units will be rack-mounted on two separate chassis and will include in addition to the electronics indicated by the block diagram, a carrier oscillator for the anemometer and the computer.

The servo motors, control transformers, differential synchro-transformers, potentiometers and gear chains, will be mounted upon two or three rack-mounted machined plates. The servo motors, control transformers, and differential synchro-transformers, are all size 23 (2.25" diameter) 60-cycle units chosen to match the characteristics of the directing synchros of the M33 Fire Control System.

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RANGE OF SQUARE ROOTING PROCESS

FIG. 2
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The above mentioned six or seven units, when rack-mounted, will comprise the entire wind correction computer. If necessary for the experimental program, the whole system can be enclosed and weatherproofed.

Electronic Components

Fig. 3 shows the details of the servo system used in square rooting. A constant voltage is applied on one grid of the difference amplifier and is compared with the amplified and rectified signal from the second potentiometer. This output is amplified to drive the servo motor in a sense that reduces the difference between the constant voltage and this rectified signal.

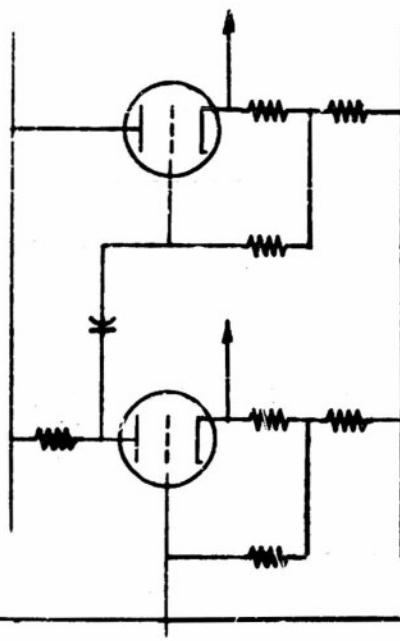
The input amplifier, Fig. 4, for the wind correction computer, which uses 60 db feedback, is designed to give a gain independent of variations of vacuum tube characteristics.

A total of 6 phase inverters appears in the computer. A single unit was designed which gives a stable gain of about 96% with a low output impedance. The simple circuit that is described in Fig. 5 very adequately fulfills the requirements.

Several types of summing amplifiers are being considered for use in the computer. It would be desirable if one type unit would suffice in all cases. Fig. 6 shows two simple summing amplifiers. A third type which is being considered is similar to the pentode type described in Fig. 6. It would involve in place of the pentode a cascode amplifier which would give the high gain characteristics of a pentode without requiring a screen voltage supply.

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PHASE INVERTER
FIG. 5

LINE VOLTAGE

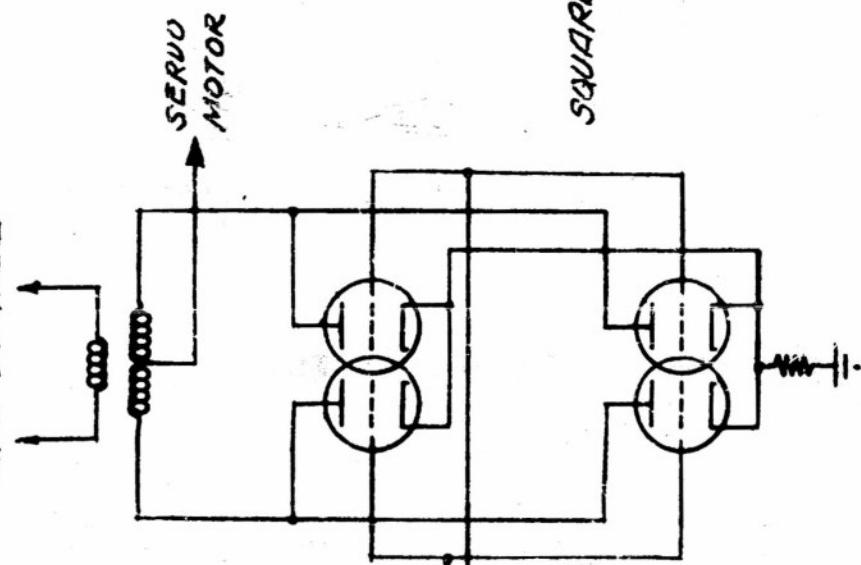
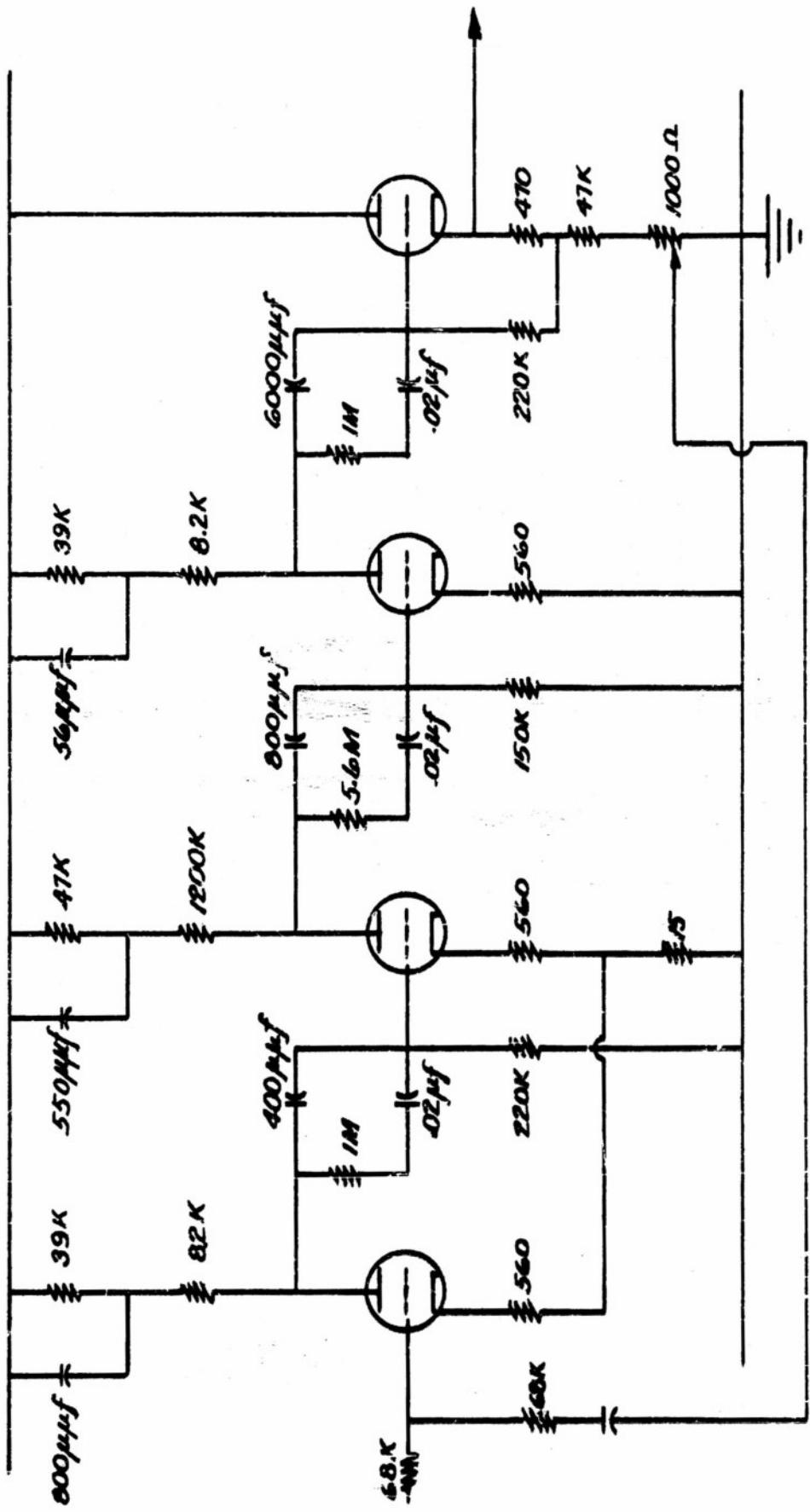


FIG. 3

SQUARE ROOTING SERVO AMPLIFIER

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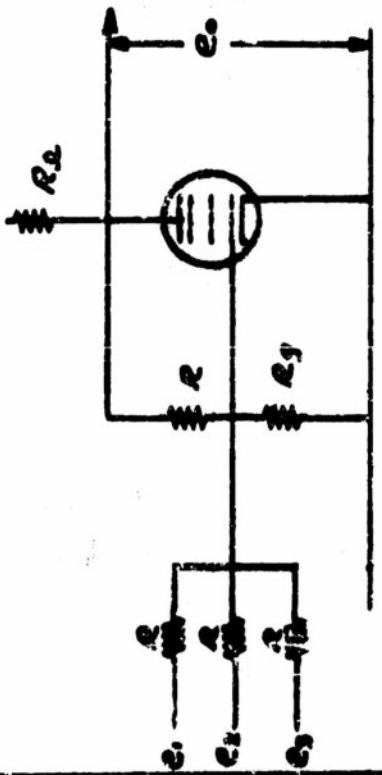


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FIG. 4

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SUMMING AMPLIFIERS

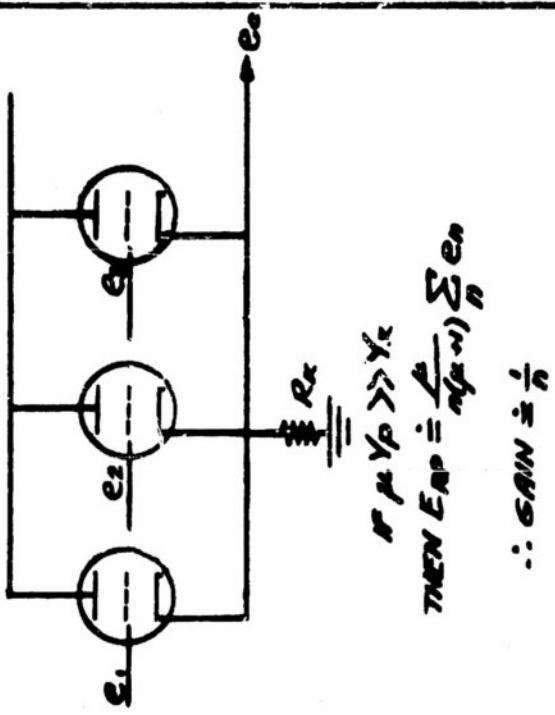


λ IS GAIN OF TUBE

$$\lambda \sum_n e_n = -\frac{e_o}{R} \frac{\partial n}{\partial e} - \frac{e_o}{R} = -\frac{e_o}{R}$$

$$\text{Hence } \lambda = e_o = -\sum_n e_n$$

GAIN \approx UNITY



$$\therefore \text{GAIN} \approx \frac{1}{\lambda}$$

FIG. 6

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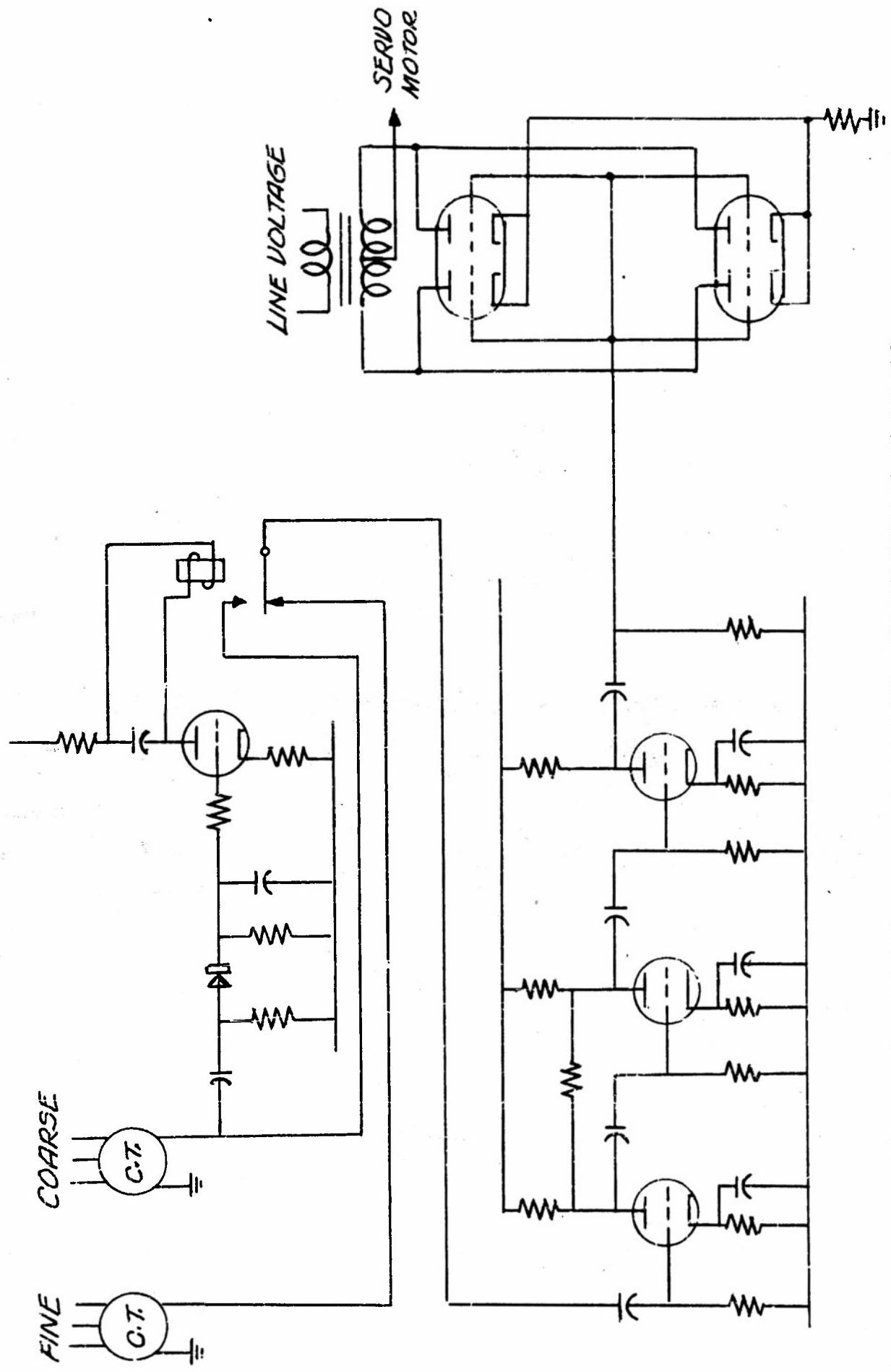
Servo Systems

Fig. 7 shows the schematic of the servo systems which are used to introduce the azimuth and elevation angles within the wind correction computer. These angles are received in the form of synchro or selsyn voltage signals transmitted from the main fire control computer. A fine-coarse balance of synchros is used for the transmission of each of the two angles; conventional techniques are utilized for the synchronization of the dual-speed balance, (Ref. 2). The synchronization circuit is shown in the upper half of Fig. 7; the lower half of Fig. 7 shows the conventional 3-stage resistance-capacitance coupled amplifier followed by a push-pull parallel power stage which controls the phase and amplitudes of the current supply to the servo motors.

The servo systems which drive the azimuth correction and elevation correction shafts are exemplified in Fig. 8. The circuit of Fig. 8 consists of essentially 4 parts: a triode amplifier stage, a cathode follower driving a transformer, a phase sensitive detector and a push-pull power stage. The phase sensitive detector makes the servo system sensitive to the phase of the a. c. error signal.

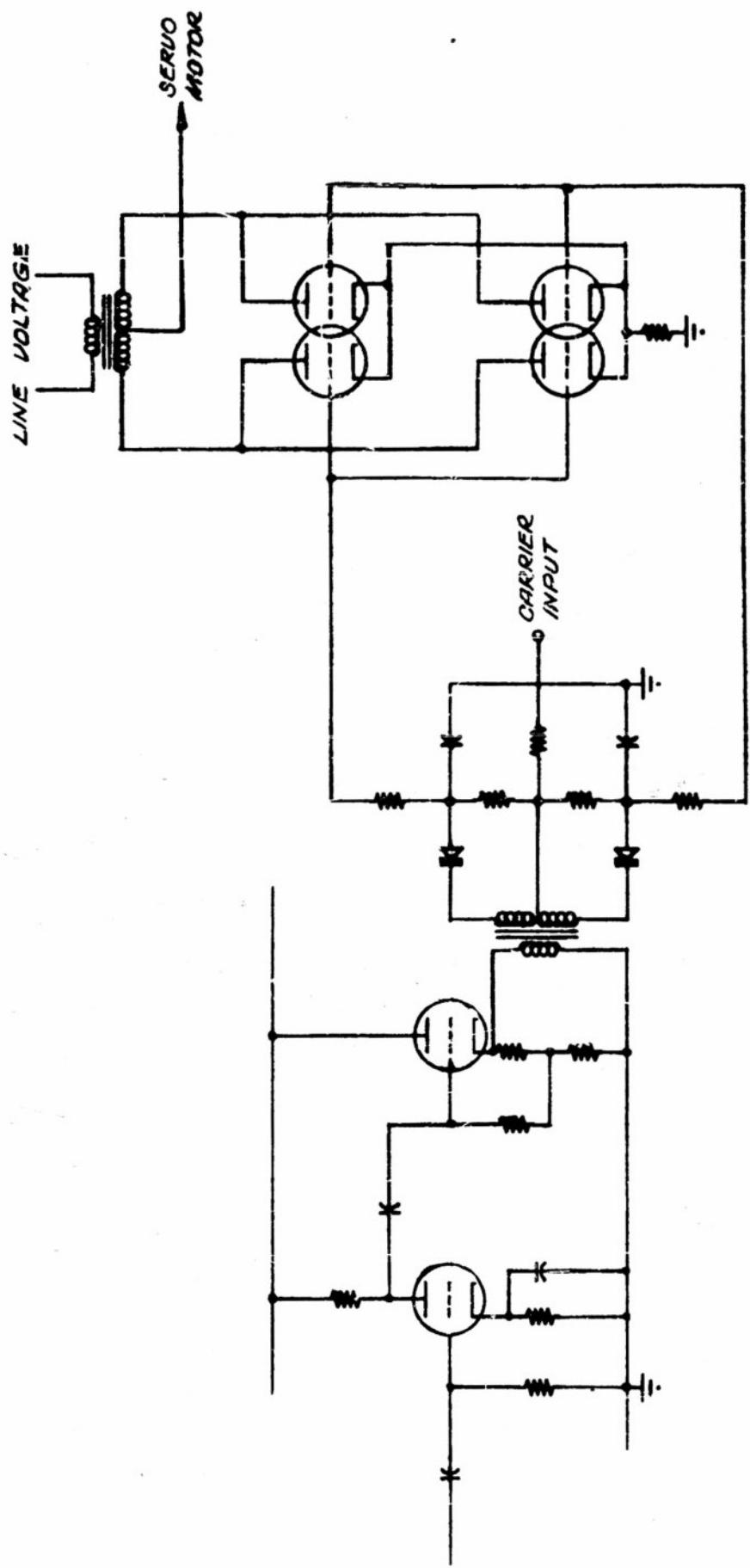
Fig. 1 shows a scale voltage applied to a sine potentiometer and to a linear potentiometer on the azimuth correction shaft. The linear potentiometer is geared with the sine potentiometer at a ratio of sixteen to one and approximates the sine function

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SERVO SYSTEM FOR AZIMUTH ELEVATION ANGLES
FIG. 7

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PHASE SENSITIVE SERVO AMPLIFIER
FIG. 8

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for small angles. At larger angles a mechanical switch puts the sine potentiometer in control. This combination offers high resolution for small angles and at the same time allows large angular corrections. Only a linear potentiometer is mounted on the elevation correction shaft, since large elevation corrections do not occur.

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1. North American Instruments, Inc., "Annual Summary for June 24, 1952 to June 24, 1953. Part I - Wind Correction Computer."
2. James, Nichols, and Phillips, "Theory of Servomechanisms", Vol. 25, p.84 et seq., McGraw-Hill, 1948.

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